

Dense Wavelength Division Multiplexing Technologies for Local Access Networks

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***presented at the DARPA Workshop on WDM
McLean, VA
April 18-19, 2000***

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 18 APR 2000		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Dense WDM Technologies for Local Access Networks				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of New Mexico				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES DARPA/MTO, WDM for Military Platforms Workshop held in McLean, VA on April 18-19, 2000, The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 11	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Low-Cost Dense Wavelength Division Multiplexing Technologies for Local Access Networks

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Objective:

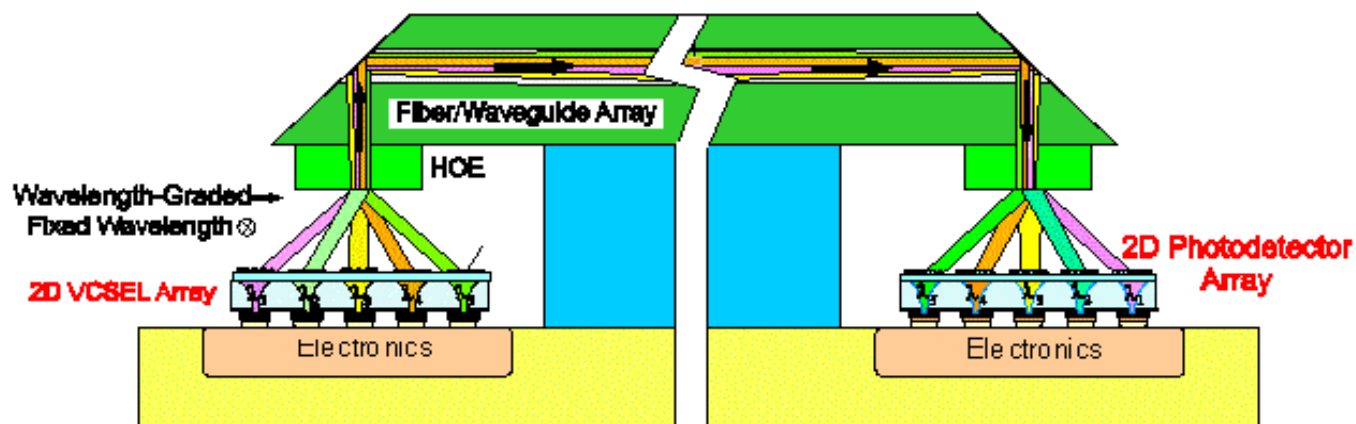
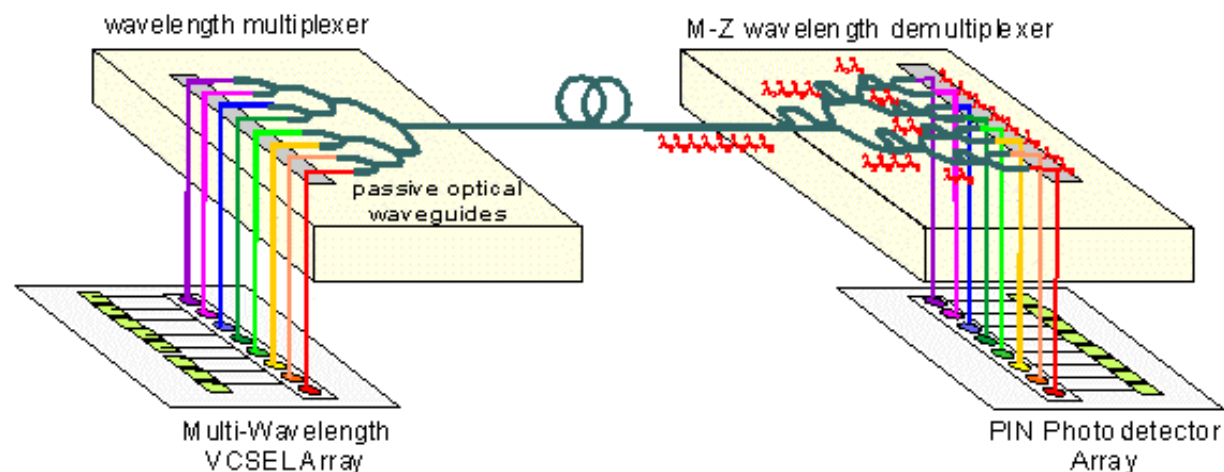
Develop a low-cost, monolithic dense WDM technology for multi-Gb/s LANs consisting of multi-wavelength VCSEL arrays (1x16) with local wavelength regulation, and an add-drop multiplexer technology for wavelength selection.

Approaches and Goals:

- **develop a quasi-planar single-growth technique for achieving multi-wavelength VCSEL and REPD arrays**
- **demonstrate local wavelength tuning to regulate the wavelengths of individual VCSELs**
- **demonstrate multi-channel WDM transmission at >2.5 Gb/s/channel**
- **achieve a 16 channel WDM VCSEL array with a channel spacing of ~2-3 nm (40 Gb/s aggregate throughput)**
- **monolithic ADM technology for wavelength selection**



Wavelength-Multiplexed Parallel Optical Interconnect using Multiple Wavelength VCSEL Arrays and a Passive Demultiplexer



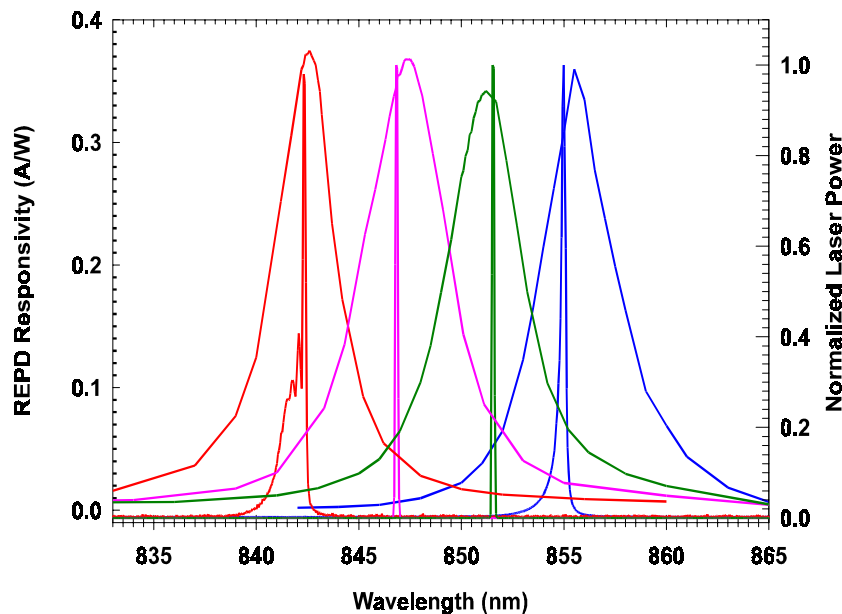
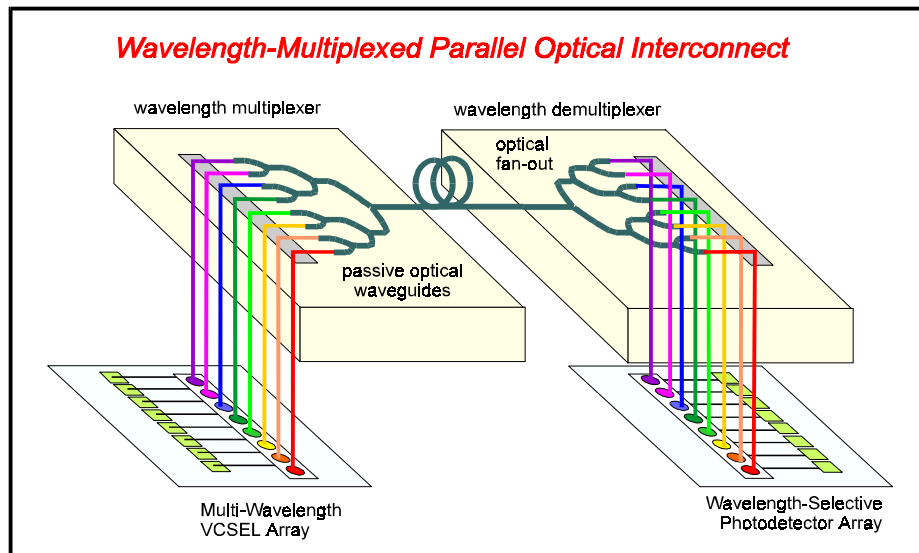
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WaveLength Division Multiplexing using Monolithic Wavelength-Graded VCSEL and Resonance Enhanced Photodetector Arrays



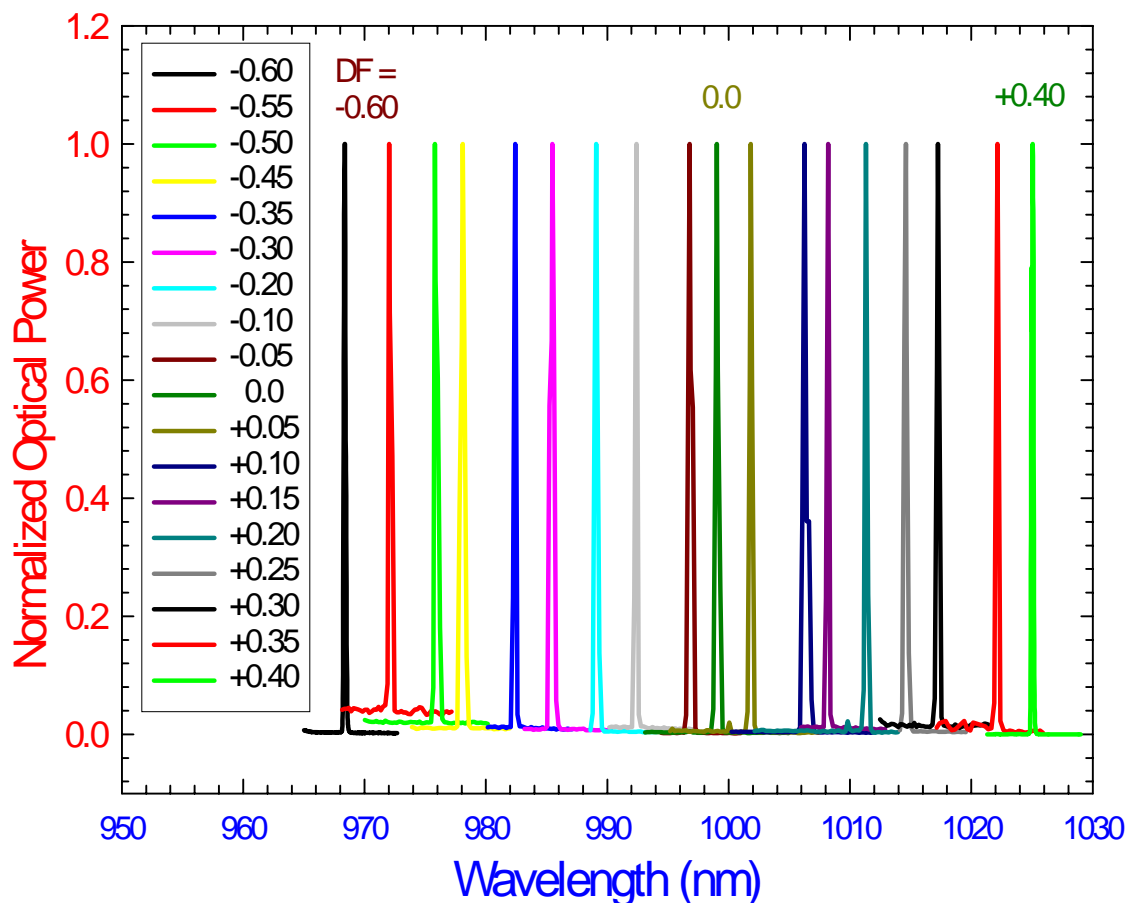
- Multiple wavelength channels can be multiplexed together using a wavelength-graded VCSEL array
- Data is demultiplexed using wavelength-selective resonance-enhanced photodetectors
- Monolithic VCSEL and REPD arrays with matching wavelengths have been achieved

Monolithic, Oxide-Confined, Multiple-Wavelength VCSEL Arrays with a 57-nm Wavelength Grading Range

Summary

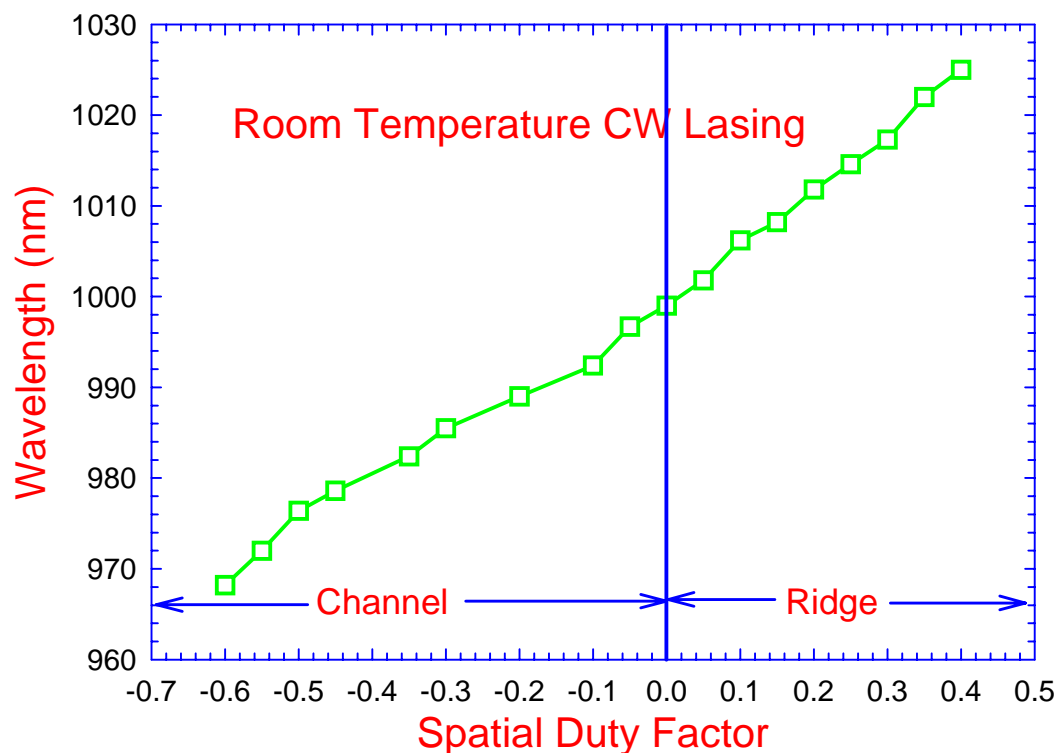
- Monolithic, multiple-wavelength, oxide-confined VCSEL arrays with a large periodic wavelength grading span of 57 nm (968 nm to 1025 nm) have been achieved under room temperature, CW lasing operation.
- Nearly linear wavelength grading is achieved with even spacing (~3 nm) by using MOCVD growth on a patterned substrate.
- An extended wavelength range is achieved by:
 - (1) scaling the growth rate of all the epilayers to minimize optical loss dispersion,
 - (2) using a selectively-oxidized upper DBR mirror with a flattened optical reflectance spectrum

The Normalized Room-Temperature CW Lasing Spectra of a Monolithic, Wavelength-Graded VCSEL Array with a 16 μ m Oxide Aperture



- The single-mode cw lasing spectra are almost evenly spaced over a 57 nm wavelength range (968 -1025 nm)

Room-Temperature CW Lasing Wavelength for Individual Elements of a Monolithic Wavelength-Graded VCSEL Array as a Function of the Spatial Duty Factor



- The spatial duty factor:
 $DF = \pm(1 - w/p)$
- w = width of channel (-) or ridge (+)
 $p = 250 \mu\text{m}$ pitch
- linear array of VCSEL's each with a $16 \mu\text{m}$ oxide aperture
- room temperature CW lasing operation with a wavelength grading span of 57 nm

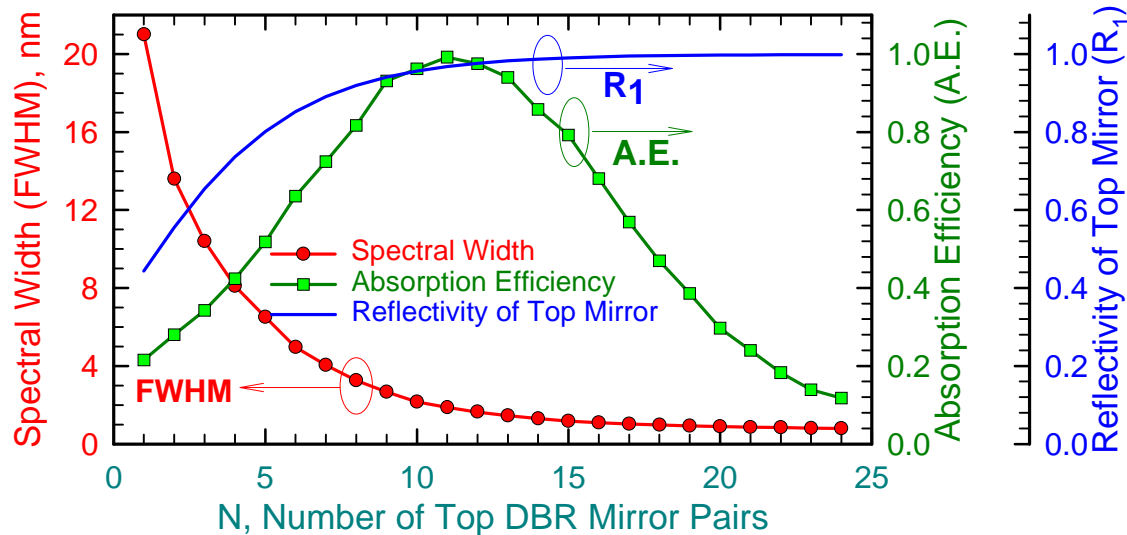
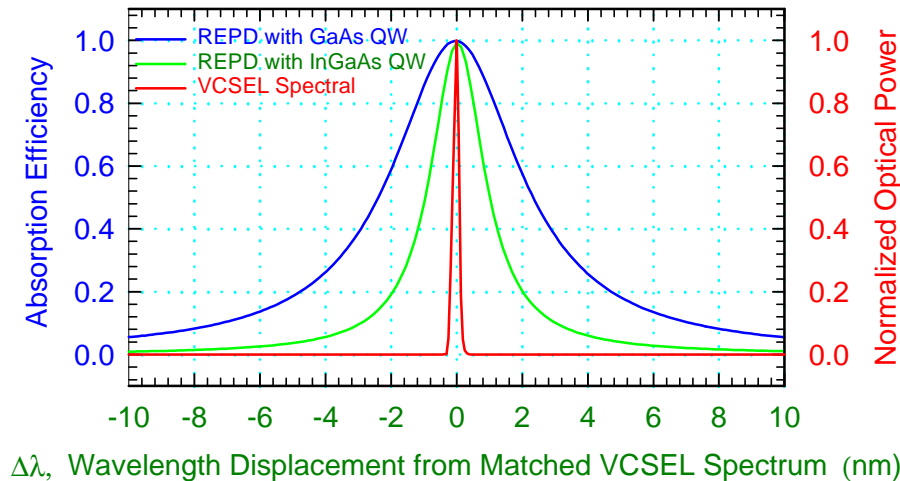
Monolithic Integration of the VCSEL and the Resonance Enhanced Photodetector on the Same Epilayer Structure for Closer Wavelength Matching

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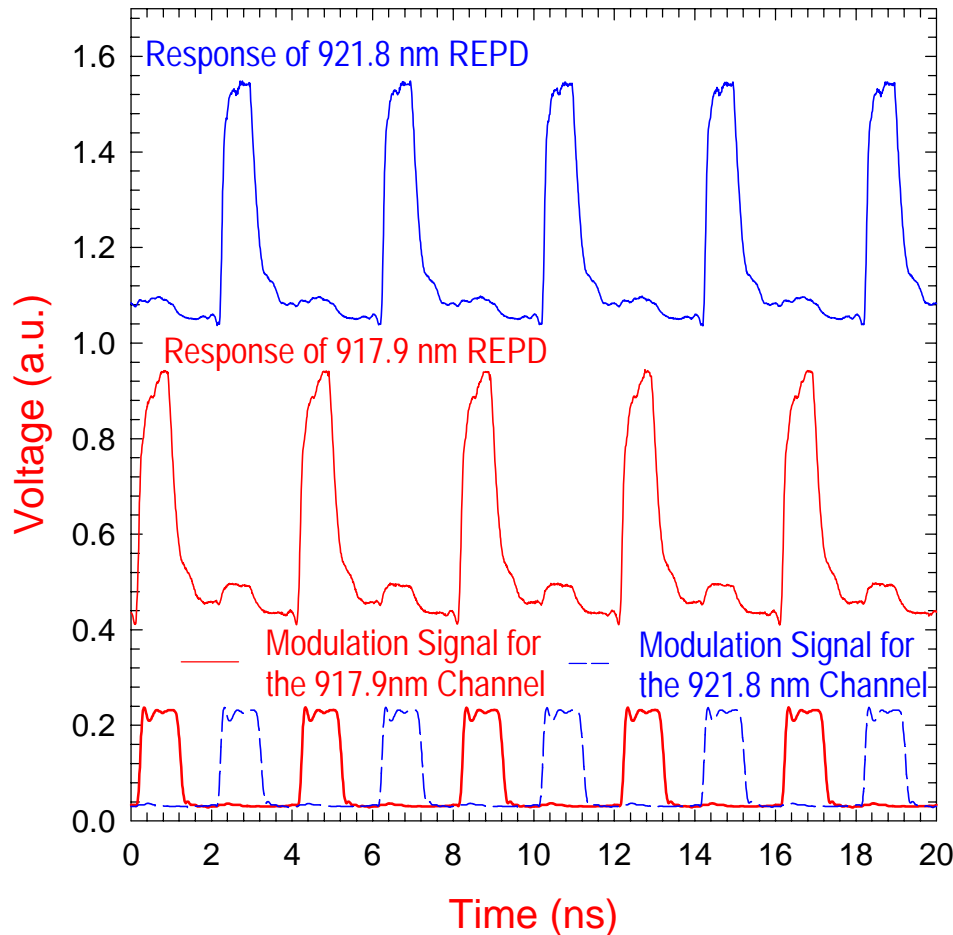
- The REPD shares the same resonance cavity with the VCSEL, and thus has a closely matched resonance wavelength
- REPD's are obtained by removing an optimum number of DBR pairs from the upper mirror of the VCSEL
- VCSEL and REPD performance are individually optimized

Advantages of InGaAs MQW's over GaAs MQW's:

- Improved wavelength selectivity (lower optical crosstalk, higher channel density)
- More optimum trade-off between absorption efficiency and wavelength selectivity (more uniform REPD arrays).



Wavelength Demultiplexing of Two High Speed Modulated Data Channels Using REPD's with a 4 nm Resonance Wavelength Separation

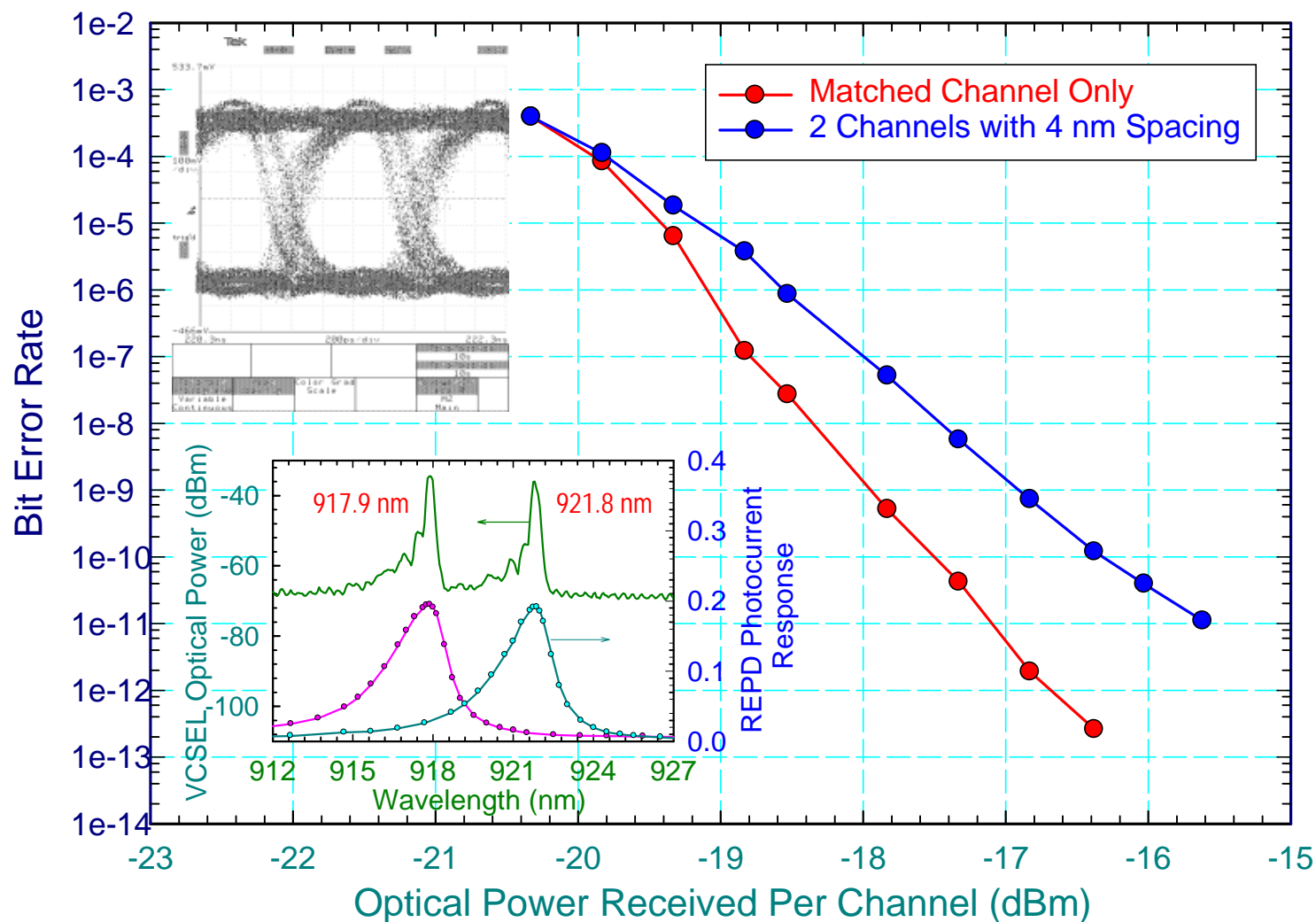


- Two wavelength multiplexed channels with a 4 nm spacing
- Each channel is modulated by 500 Mb/s RZ, 1 ns wide pulses
- Demultiplexing is achieved using REPD's, with an ac crosstalk level of ~ -10 dB

Transmission Performance of a 2-Channel WDM Link with a 4 nm Wavelength Separation at 1 Gb/s per Channel, Showing the Effect of Optical Crosstalk

Upper inset: eye diagram@ BER=10⁻¹¹

Lower inset: emission spectra of VCSELs and responsivity of REPDs



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